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Which comes first in the U.S. Arctic – the tidal datum or the shoreline position?

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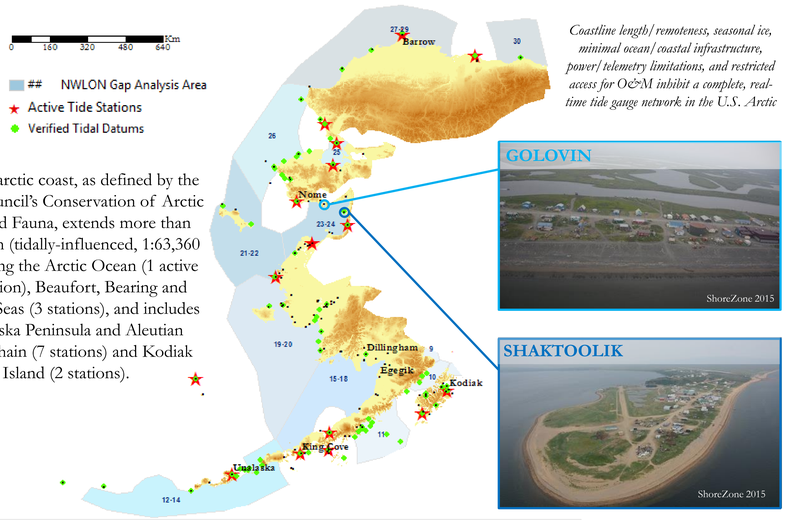
Setting



The U.S. arctic coast, as defined by the Arctic Council's Conservation of Arctic Flora and Fauna, extends more than 50,000 km (tidally-influenced, 1:63,360 scale) along the Arctic Ocean (1 active tide station), Beaufort, Bearing and Chukchi Seas (3 stations), and includes the Alaska Peninsula and Aleutian Island Chain (7 stations) and Kodiak Island (2 stations).

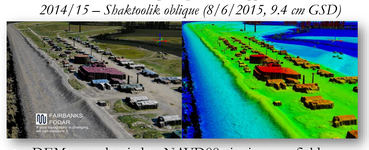
Coastline length/remoteness, seasonal ice, minimal ocean/coastal infrastructure, power/telemetry limitations, and restricted access for O&M inhibit a complete, real-time tide gauge network in the U.S. Arctic

Experimental Hybrid Technique

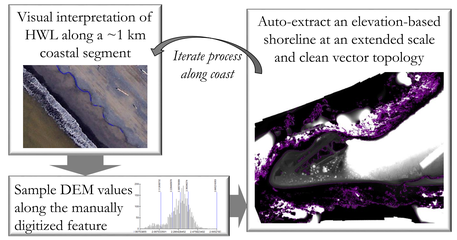
Note: this approach is not in use or certified by NOAA and it has been developed for use in non-navigation/charting applications

Requirements:

- Inherently co-registered, high-resolution DEM and orthoimage (calm waves; low tide)
  A regional dataset was acquired in western Alaska using the Structure From Motion photogrammetric approach in 2014/15 – Shaktoolik oblique (8/6/2015, 9.4 cm GSD)



- DEM must be tied to NAVD88 via rigorous field control to produce datum offset values
  2015 ground control point; processed in OPUS-Projects



Critically evaluate appropriateness of the HWL for use as a MHW datum proxy.

Consider:

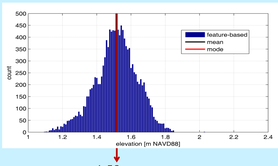
- time of collection/tidal phase
- wave conditions
- beach state

$$Bias = (X_{SWL} - X_{MHW}) = \frac{\left[Z_T + 1.1\left(0.35\tan\beta(H_o L_o)^{0.5} + \frac{\left[H_o L_o (0.563\tan\beta^2 + 0.004)\right]^{0.5}}{2}\right)\right] - Z_{MHW}}{\tan\beta}$$

X_{SWL} is the position of the HWL shoreline, X_{MHW} is the position of the MHW shoreline, Z_T is the tide level, Z_{MHW} is the elevation of MHW, $\tan\beta$ is the beach slope, H_o is the deepwater significant wave height, and L_o is the deepwater wave length given by linear theory as $gT^2/2\pi$, where g is the acceleration due to gravity, and T is the peak wave period.

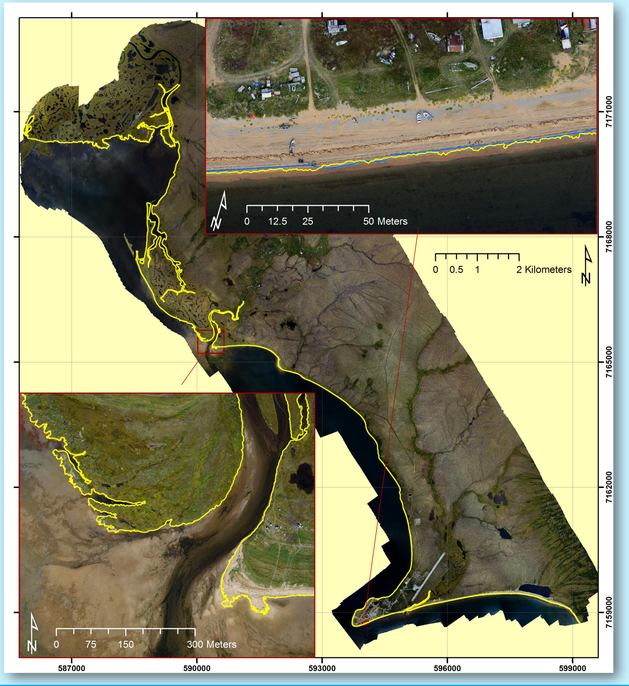
HWL elevation value may be adjusted to more closely align with MHW under wave conditions with proxy datum bias calculation (Ruggiero and List, 2009).

Applied Use – Golovin, Alaska



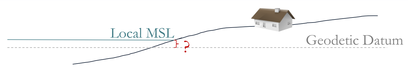
1.52 m
= estimated NAVD88/LMHW offset value

- No verified datum offset values exists for Golovin, Alaska
- Estimated datum offset is approximately 25 cm greater than an offset calculated from a NAVD88-leveled 3 month water level record in 2013 (Smith 2014)
- Over 40 km of consistent, repeatable, and tide-correlated shoreline was mapped and edited for Golovin in an accelerated 2 hour timeframe (shown in yellow below)



Challenges

"Historically, the need to supply a tidal datum offset for a given location was met by simply using the offset at the nearest water level station."
- CSDL, 2012

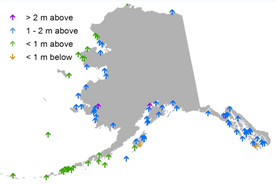


A conversion factor between local water levels and elevations on land is needed for:

- Combining bathymetry and topography into seamless coastal elevation surfaces
- Relating storm surge forecasts to elevations on land
- Highly consistent and rapid datum-based shoreline mapping

The VDatum tool, which allows for vertical transformation of geospatial data, is not presently available in Alaska; tidal datum offsets are limited to a sparse constellation of locations→

VDatum Coverage



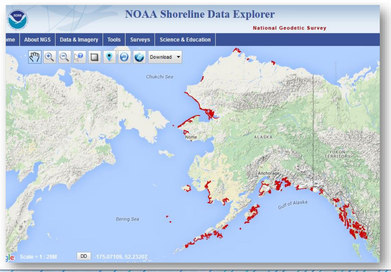
Position of Local MSL relative to NAVD88(GEOID12B) in meters

"Less than 10% of Alaska has contemporary shoreline data [1960 or newer] and less than 1% is mapped annually."
–National Geodetic Survey, Coastal Mapping Program, 2012

"[Steps to enable] safe marine operations and transportation in the Arctic… [will include] a joint effort among NOAA, USGS and the State of Alaska to coordinate on satellite imagery analysis and other technologies for shoreline and near-shoreline coastal mapping…" *–White House Press Secretary, Fact Sheet, Sept. 2015*

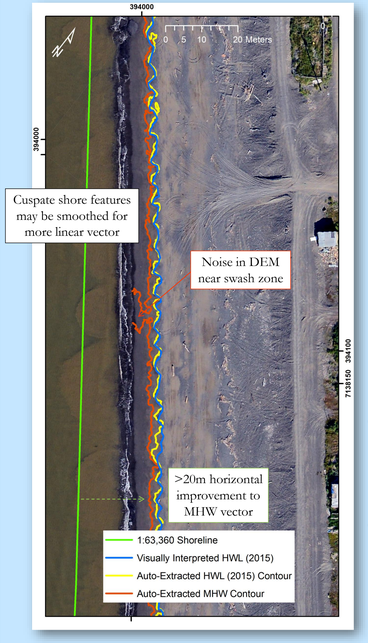
The most contemporary vector that defines the shoreline position in Alaska is the Continually Update Shoreline Product (CUSP), a compilation of NOAA and non-NOAA shoreline features (linked to Mean High Water [MHW] when possible) that have primarily been obtained from visual interpretation of satellite imagery and orthorectified aerial photography.

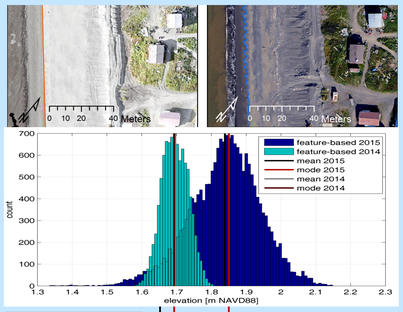
Despite documented rates of rapid shoreline change in the arctic, the vast linear extent, remoteness, and limited ice-free season create unique challenges in maintaining an updated shoreline vector for the Alaska coast.



Present status of CUSP coverage in Alaska.
http://www.ngs.noaa.gov/NSDE/

Evaluation – Shaktoolik, Alaska

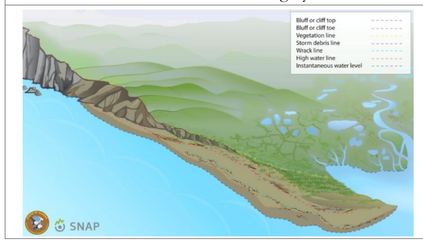
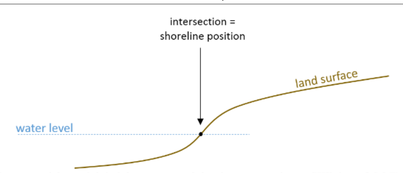




1.65 m based on datum offset at tidal benchmark 8691 A 2010 (DGGS, 2015)

- 2015 and 2014 MHW datum offset, as estimated w/ HWL proxy with no datum bias estimate applied, differed by 16 cm; 2015 shoreline exhibits cuspate morphology consistent with higher wave energy
- HWL proxy elevation exceeded verified tidal datum by 4 to 20 cm; on slopes typical of western Alaska beaches this translates to an estimated 6 m horizontal error in the MHW shoreline position (IHO standards require offset of <20 m for coastlines of less significance to navigation)

Approaches to Shoreline Mapping

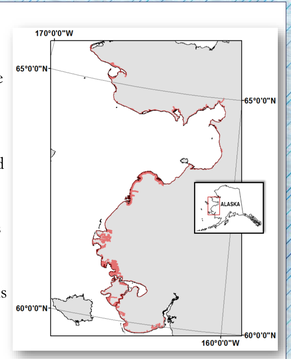
Feature- Based	Datum-Based
Delineation (often manual) using a shoreline proxy feature or tide coordinated imagery.	Automated feature extraction at the intercept of a high-resolution DEM and a tidal datum surface (contoured datum elevation)
	

Very rapid and highly repeatable, but requires (White, 2007):

- Accurate, high resolution DEM
- Known offset between NAVD88 and tidal datums at coast

Next Steps

- Ability to rapidly and consistently re-map shoreline in a is important in areas undergoing rapid change
- Preliminary results suggest that shoreline vectors derived in this manner are comparable to existing, contemporary MHW vectors (< 10 m horizontal offset)
- State of Alaska will map ~3,500 km of coast with this technique in 2016; vectors will be submitted to NOAA for CUSP consideration



Acknowledgements

The views and conclusions contained on this poster are those of the authors and should not be interpreted as representing the opinions or policies of the U.S. Government. Mention of trade names or commercial products does not constitute their endorsement by the U.S. Government.

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